

Finite Spectrum Assignment Controller for Teleoperation Systems with Time delay

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Abstract

In this paper, two controllers are proposed for bilateral teleoperation systems with communication time delay. The first one guarantees the tracking of slave-master outputs, while the second one guarantees the transparency. Communication time delay appears in the control loop of the second controller, and finite spectrum assignment method is used to design this controller such that the resulting closed loop system have a desirable finite spectrum. Numerical example shows that both tracking and transparency can be guaranteed using the proposed method.

Keywords: Bilateral teleoperation systems, Time delay systems, Finite spectrum assignment (FSA).

1 Bilateral teleoperation system

In bilateral teleoperation system, the slave (remote) manipulator is controlled by an operator through the master (local) manipulator, while the contact force of the slave manipulator with the environment is reflected back to the operator through the master manipulator as shown in Figure 1.

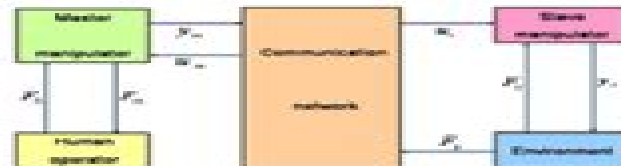


Figure 1: Bilateral teleoperation system.

In this configuration, the operator applies a force F_o on the master manipulator in order to drive it to the desired position or velocity y_m . The master manipulator assumes to work in a free space, i.e. there is no reaction force from the manipulator to the operator, or in other words, the operator can drive the master manipulator to any desired position or velocity. The output of the master manipulator is sent forward to the remote manipulator through the communication network and is considered as a reference for the slave manipulator (desired position or velocity). This reference is used to generate a torque (or a force) u_s which drives the slave manipulator to certain position or velocity y_s . Assuming that the slave manipulator acts in a non-free environment, there will be a reaction torque (or force) F_r . This force sensed at the environment F_r , or a function of this force F_r , is sent back to the master manipulator and used to generate a feedback torque (or force) F_m which is applied to the master manipulator in order to give the operator a sense of what is happening in the remote side.

A controller should be designed for the previous scheme in order to guarantee:

1. *The tracking: the slave manipulator's output y_s has to track the master manipulator's output y_m , i.e. $\lim_{t \rightarrow \infty} (y_s(t) - y_m(t)) = 0$.*
2. *The transparency: the feedback force F_m has to track the contact force F_r , or a function of this force F_r , i.e. $\lim_{t \rightarrow \infty} (F_m(t) - F_r(t)) = 0$.*

In the case where there is a time delay in the communication network, it should be incorporated in the designing method such that the previous objectives still maintain.

An approach used to solve the above problem is based on the passivity and scattering theory [1]: if the input power flow does not exceed the output power flow for

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